USE OF SPATIAL INFORMATION IN CLASSIFICATION OF REMOTELY SENSED DATA

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ABSTRACT

In this report we discuss the use of spatial information for improving classification accuracy of remotely sensed data. In particular a simple example (the unanimous four nearest neighbor rule) is discussed and its results are presented. This algorithm results in improved classifications accuracy (one to five percentage points) and costs little in execution time. Other schemes for improving classification accuracy are also discussed.

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Presently most remote sensing classification algorithms treat each data element independently of its (spatial) neighbors. In many instances, though, a point is most likely to be like its nearest neighbors. This is particularly true in the agricultural case when the average field contains many data elements. Therefore, use of this information should lead to higher classification accuracies.

We devised a simple scheme to test this theory. This algorithm makes two assumptions:

1) the majority of fields contain many data points
2) the initial classification was "good" (i.e. accurate enough to propogate correct classifications)

All points are classified in the usual manner, using the maximum likelihood classifier of LARSYS. A second pass is then made on the classified data points, keeping three adjacent scan lines in core simultaneously. The four nearest neighbors (4NN) of each point are examined. If all of the 4NN are classified the same and the point in question is classified differently, then we assume that it has been classified incorrectly and change its classification. For example, consider the classified points in Fig. 1. The "R" in row 2 would then be changed to a "C", whereas the "X" in row 2 would not be modified.

We added this algorithm to the OS version of LARSYS operating on our IBM 370/155. Since a second pass on the classified data is required for thresholding and generating the display map, no additional pass was necessary to incorporate this algorithm.

Data from two flight lines (C1 and 210) was used to test its performance. In all cases examined the classification accuracy improved or did not change. The classification accuracy improved by as much as five percentage points, with total classification accuracy in the 85% - 98% range. Fig. 2 shows some typical results for training and test classes for various values of the threshold. Execution time for this algorithm is negligible.

Many similar algorithms are now apparent and should be investigated (e. g. if 7 of the 8 nearest neighbors are the same, the point in question should also be). Two schemes that appear promising and utilize the four nearest neighbors are described below. We will use the notation X_i, i=0,1,2,3,4 where X_o is the point in question and X_1, X_2, X_3, and X_4 are its four nearest neighbors. And let us denote by $f_p(X_i)$ the value of the probability density function for class p for point X_i.

1) Form $\Lambda_{ij}(X_p) \equiv f_i(X_p) / f_j (X_p)$, j>i

   for all m classes. Then form

   $$L_{ij} (X_o) = \frac{1}{8} \left(4 \Lambda_{ij} (X_o) + \sum_{k=1}^{4} \Lambda_{ij} (X_k)\right)$$

   To classify the point X_o, we will assign it to class i' where $L_{i'j'}$ is the maximum L_{ij}. Note that this maximum may be found by a table look-up approach and therefore only a few of the L_{ij}'s need be computed. This algorithm locally smooths ratio of density functions. An alternate approach would be to smooth the densities themselves. Also other weighting functions (like L_{ij}) could be used.

2) This method is a thresholding algorithm. We begin by forming

   $$R_j(X_o) = \frac{1}{8}\left(4f_j (X_o) + \sum_{k=1}^{4} f_j (X_k) \right)$$

   Then if R_{j1} and R_{j2} are the largest and second largest R_j's, respectively, we compute R_{j1}/R_{j2}. If this ratio is larger than some empirically determined constant k, then we assign X_o to class j_1, otherwise X_o is assigned to an undefined class.

These and similar schemes should be investigated to determine what assumptions about the data are necessary for each to considerably improve the classification accuracy. The important point to note is that the algorithms should be easy to implement, cost little ın execution time and could significantly improve classification accuracy.

APPENDIX

Subroutine DISPLY

This LARSAA routine was modified to include the 4NN algorithm. In this implementation thresholded points were not propagated, i.e. if 4 thresholded points surround a nonthresholded point, that point is not modified. No other changes to LARSAA were necessary. Modified statements are those appearing without statement numbers.

```
      COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=44,SIZE=0000K,
                    SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,XREF
              C     //DISPLY                                                   00C01000
              C*****************************************************************00002000
              C                                                                *00003000
              C DISPLY      REVISED 06/10/71 PWS                               *00004000
              C                                                                *00005000
              C             TABULATE CLASSIFICATION RESULTS AND PRINT PICTORIAL *00006000
              C             CLASSIFICATION MAP                                 *00007000
              C                                                                *00008000
              C*****************************************************************00009000
  ISN 0002          SUBROUTINE DISPLY(CON,TRNFLD,TSTFLD,TRNTAB,TSTTAB,LINID,IR,VR,*)  00010000
              C*****************************************************************00011000
              C                                                                *00C12000
              C DEFINE FROGRAM VARIABLES                                       *00013000
              C                                                                *00014000
              C*****************************************************************00015000
  ISN 0003          COMMON/GLOCCN/  CONPUT,DATAPE,FILESV,HEAD,ID,MAPSAV,MAPTAP,    00016000
                *                   MAXCHA,MAXCLS,PAGSIZ,READIN,SAVTAP         00C17000
              C                                                                00C18000
  ISN 0004          INTEGER*4       CONPUT,DATAPE,FILESV,HEAD(79),ID(200),MAPSAV,  00019000
                *                   MAPTAP,MAXCHA,MAXCLS,PAGSIZ,READIN,SAVTAP  00020000
              C                                                                00021000
  ISN 0005          REAL*4          FRQCAL(5,30)                               00022000
  ISN 0006          INTEGER*4       COMENT(16),CURRUN,DATE(5),DATSAV,HED1(16),  00023000
                *                   HED2(16),TIME(5)                           00C24000
              C                                                                00025000
  ISN 0007          EQUIVALENCE     (DATSAV,ID(1)),(CURRUN,ID(3))              00026000
  ISN 0008          EQUIVALENCE     (ID(51),FRQCAL(1,1))                       00027000
  ISN 0009          EQUIVALENCE     (HED1(1),HEAD(8)),(DATE(1),HEAD(26))       00028000
  ISN 0010          EQUIVALENCE     (HED2(1),HEAD(37)),(TIME(1),HEAD(55))      00029000
  ISN 0011          EQUIVALENCE     (COMENT(1),HEAD(63))                       00C30000
              C*****************************************************************00031000
              C                                                                *00032000
              C                   GLOBAL CCMMON VARIABLES USED IN AIRANAL      *00033000
              C                                                                *00034000
              C COMENT = ARRAY FOR STORING A 64 CHARACTER COMMENT              *00035000
              C CONPUT = CCMPUTED-GO-TO VARIABLE (CONPUT,READIN = 1,5 OR 2,15) *00036000
              C CURRUN = CURRENT RUN NUMBER ON DATA TAPE                       *00037000
              C DATAPE = FORTRAN UNIT NUMBER FOR AIRCRAFT DATA STORAGE TAPE    *00038000
              C DATE   = ARRAY FOR STORING DATE OF PROGRAM EXECUTION           *00039000
              C DATSAV = CURRENT MOUNTED DATA TAPE                             *00040000
```

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C FILESV = FILE NUMBER LOCATION FOR MAP TAPE                                   *00041000
C FRQCAL = EQUIVALENCED TO ID(51,200)                                          *00042000
C FRQCAL(1,N) = LOWER LIMITS OF SPECTRAL BANDS ON TAPE                         *00043000
C FRQCAL(2,N) = UPPER LIMITS OF SPECTRAL BANDS ON TAPE                         *00044000
C FRQCAL(3,N) = VALUE OF C0 ON TAPE                                            *00045000
C FRQCAL(4,N) = VALUE OF C1 ON TAPE                                            *00046000
C FRQCAL(5,N) = VALUE OF C2 ON TAPE                                            *00047000
C FRQCAL = WAVELENGTH,C0,C1,C2 FOR THE CHANNELS IN THE CURRENT RUN             *00048000
C HEAD   = VARIABLE FORMAT FOR PRINTING PAGE HEADER                            *00049000
C HED1   = ARRAY FOR STORING A 64 CHARACTER FIRST LINE HEADER                  *00050000
C HED2   = ARRAY FOR STORING A 64 CHARACTER SECOND LINE HEADER                 *00051000
C ID     = ARRAY FOR STORING IDENTIFICATION OF AIRCRAFT DATA SET               *00052000
C ID(1)       = LARS TAPE NUMBER                                               *00053000
C ID(2)       = FILE NUMBER ON THIS TAPE                                       *00054000
C ID(3)       = RUN NUMBER                                                     *00055000
C ID(4)       = CONTINUATION CODE                                              *00056000
C ID(5)       = NUMBER OF DATA CHANNELS ON ADST (30 MAXIMUM)                   *00057000
C ID(6)       = NUMBER OF DATA SAMPLES PER CHANNEL PER LINE ON ADST            *00058000
C ID(7-10)    = FLIGHT LINE IDENTIFICATION (16 CHARACTERS)                     *00059000
C ID(11)      = MONTH DATA WAS TAKEN                                           *00060000
C ID(12)      = DAY DATA WAS TAKEN                                             *00061000
C ID(13)      = YEAR DATA WAS TAKEN                                            *00062000
C ID(14)      = TIME DATA WAS TAKEN                                            *00063000
C ID(15)      = ALTITUDE OF AIRCRAFT ABOVE TERRAIN WHEN DATA WAS TAKEN         *00064000
C ID(16)      = GROUND HEADING OF AIRCRAFT WHEN DATA WAS TAKEN                 *00065000
C ID(17-19)   = DATE OF REFORMATING                                            *00066000
C ID(20-50)   = ALL ZERO (TO BE DEFINED LATER)                                 *00067000
C ID(51)      = LOWER LIMIT OF SPECTRAL BAND ONE ON TAPE                       *00068000
C ID(52)      = UPPER LIMIT OF SPECTRAL BAND ONE ON TAPE                       *00069000
C ID(53)      = VALUE OF C0 BASED ON PREPROCESSING CALCULATIONS(CHAN 1)*00070000
C ID(54)      = VALUE OF C1 BASED ON PREPROCESSING CALCULATIONS(CHAN 1)*00071000
C ID(55)      = VALUE OF C2 BASED ON PREPROCESSING CALCULATIONS(CHAN 1)*00072000
C ID(56-200)  = REPEAT OF ID(51-55) FOR UP TO ID(5) CHANNELS                   *00073000
C ID(56-200)  = 0.0 FOR NONEXISTING DATA CHANNELS                              *00074000
C MAPSAV = CURRENT MOUNTED MAP TAPE                                            *00075000
C MAPTAP = FORTRAN UNIT NUMBER FOR MAP TAPE                                    *00076000
C MAXCHA = MAXIMUM NUMBER OF CHANNELS ALLOWED                                  *00077000
C MAXCLS = MAXIMUM NUMBER OF CLASSES ALLOWED                                   *00078000
C PAGSIZ = MAXIMUM NUMBER OF LINES PER PRINTER PAGE                            *00079000
C READIN = FORTRAN UNIT FOR READING MONITOR + SUPERVISOR CONTROL CARDS *00080000
C SAVTAP = FORTRAN UNIT NUMBER FOR SAVE DISK                                   *00081000
C TIME   = ARRAY FOR STORING THE TIME OF PROGRAM EXECUTION                     *00082000
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           C***********************************************************************00C83000
ISN 0012         COMMON/DISCCM/  GRPNAM,CLSNAM,LWORK,THRES,THSCNT,RUNNUM,CALC,      00084000
                *                SERIAL,NOMAPS,STATKY,OTRKY,OTSKY,TRCLS,TRFLD,      00085000
                *                TSFLD,TSCLS,PCT,NOFET5,NOCLS5,NOGRPS,NOCLS,CCPIES,00086000
                *                SYMCNT,NOFLD,NOTST,LISTKY,LIN2,RDCNT,WRCNT,STOPCD,00
                *                INFO,CLSDAT,SAVMAP,                                00088000
                *                SAVLIN,                                            00089000
                *                FETVEC,CSEL,GRPSTK,BLOCK,                          00090000
                *                SYMMTX                                             00091000
           C                                                                        00092000
ISN 0013         REAL*8          GRPNAM(61),DWORK1(14),DWORK2(15),CLSNAM(60)        00093000
ISN 0014         REAL*4          THRES(2,60),RWORK(30)                              00094000
ISN 0015         INTEGER*4       THSCNT,RUNNUM,CALC,SERIAL,NOMAPS,STATKY,OTRKY,     00095000
                *                OTSKY,TRCLS,TRFLD,TSFLD,TSCLS,PCT,NOFET5,NOCLS5,   00096000
                *                NOGRPS,NOCLS,CCPIES,SYMCNT,NOFLD,NOTST,LISTKY,     00097000
                *                CILIN,CLLIN,CLINT,CISAM,CLSAM,CSINT,CRUN,LIN2,     00098
                *                RDCNT,WRCNT,STOPCD,SAVMAP,INFO(17),IWORK(30),      00099000
                *                CLSDAT(5)                                          00100000
ISN 0016         LOGICAL*4       SAVLIN                                             00101000
ISN 0017         INTEGER*2       FETVEC(30),CSEL(30),GRPSTK(60),BLOCK(28),          00102000
                *                HWORK(60),DILIN,DLLIN,DLINT,DISAM,DLSAM,DSINT,IPT,00103000
                *                LPT,PINT,PISAM,PLSAM,PPINT,PSINT,LEAD,LAG,NFC,NDW,00104000
                *                PTS,RILIN,RLLIN,RLINT,RISAM,RLSAM,RSINT,CALTRN,    00105000
                *                CALTST                                             00106000
ISN 0018         LOGICAL*1       SYMMTX(64),LWORK(128),WE(2),WE2                    00107000
           C                                                                        00108000
ISN 0019         EQUIVALENCE     (INFC(1),CRUN),(INFO(4),CILIN),(INFO(5),CLLIN)     00109000
ISN 0020         EQUIVALENCE     (INFC(6),CLINT),(INFO(7),CISAM),(INFO(8),CLSAM)    00110000
ISN 0021         EQUIVALENCE     (INFC(9),CSINT)                                    00111000
ISN 0022         EQUIVALENCE     (BLOCK(1),RILIN),(BLOCK(2),RLLIN),(BLOCK(3),RLINT)00112000
ISN 0023         EQUIVALENCE     (BLOCK(4),RISAM),(BLOCK(5),RLSAM),(BLOCK(6),RSINT)00113000
ISN 0024         EQUIVALENCE     (BLOCK(7),IPT),(ELCCK(8),LPT),(BLOCK(9),PINT)      00114000
ISN 0025         EQUIVALENCE     (BLOCK(10),PISAM),(BLOCK(11),PLSAM)                00115000
ISN 0026         EQUIVALENCE     (BLOCK(12),PSINT),(BLOCK(13),LEAD)                 00116000
ISN 0027         FQUIVALENCE     (BLOCK(14),LAG),(BLOCK(15),NPD)                    00117000
ISN 0028         EQUIVALENCE     (BLOCK(16),NDW),(BLOCK(17),PPINT)                  00118000
ISN 0029         EQUIVALENCE     (BLOCK(18),PTS)                                    00119000
ISN 0030         EQUIVALENCE     (BLOCK(19),DILIN),(BLOCK(20),DLLIN)                00120000
ISN 0031         EQUIVALENCE     (BLOCK(21),DLINT),(BLOCK(22),DISAM)                00121000
ISN 0032         EQUIVALENCE     (BLOCK(23),DLSAM),(BLCCK(24),DSINT)                00122000
ISN 0033         EQUIVALENCE     (BLOCK(25),CALTRN),(BLOCK(26),CALTST)              00123000
ISN 0034         EQUIVALENCE     (DWORK1(1),DWORK2(1)),(DWORK1(1),RWORK(1))         00124000
ISN 0035      EQUIVALENCE    (DWORK1(1),HWORK(1)),(DWORK1(1),LWORK(1))             00125000
ISN 0036      EQUIVALENCE    (LWORK(120),WE(1)),(WE(2),WE2)                         00126000
ISN 0037      EQUIVALENCE    (DWORK1(1),IWORK(1))                                   00126100
        C*********************************************************************00127000
        C                                                                      *00128000
        C        DISPLAY COMMON VARIABLES USED IN AIRANAL                      *00129000
        C                                                                      *00130000
        C BLOCK  = AREA TO BE DISPLAYED                                        *00131000
        C CALC   = FLAG TO CALCULATE ONLY EXACT AREA DISPLAYED                 *00132000
        C CILIN  = FIRST LINE CLASSIFIED                                       *00133000
        C CISAM  = FIRST SAMPLE CLASSIFIED                                     *00134000
        C CLINT  = LINE INCREMENT CLASSIFIED                                   *00135000
        C CLLIN  = LAST LINE CLASSIFIED                                        *00136000
        C CLSAM  = LAST SAMPLE CLASSIFIED                                      *00137000
        C CLSMTX = REDUCED CLASS NAMES                                         *00138000
        C CLSNAM = NAMES OF CLASSES                                            *00139000
        C CLSPTR = POINTER FOR CLSSTK ARRAY                                    *00140000
        C CLSSTK = STACKED CLASSES                                             *00141000
        C COPIES = NUMBER OF COPIES OF ALL TABLES                              *00142000
        C CRUN   = RUN CLASSIFIED                                              *00143000
        C CSEL   = GROUP POINTER                                               *00144000
        C CSET   = CALIBRATION VALUES                                          *00145000
        C CSINT  = SAMPLE INCREMENT CLASSIFIED                                 *00146000
        C DILIN  = DISPLAY FIRST LINE                                          *00147000
        C DISAM  = DISPLAY FIRST SAMPLE                                        *00148000
        C DLINT  = DISPLAY LINE INCREMENT                                      *00149000
        C DLLIN  = DISPLAY LAST LINE                                           *00150000
        C DLSAM  = DISPLAY LAST SAMPLE                                         *00151000
        C DSINT  = DISPLAY SAMPLE INCREMENT                                    *00152000
        C FETVEC = FEATURES USED                                               *00153000
        C GRPNAM = NAMES OF GROUPED CLASSES                                    *00154000
        C GRPSTK = STACKED GROUPS                                              *00155000
        C INFO   = 17 WORD ARRAY FOR STORING LARS12 CARD INFORMATION           *00156000
        C IPT    = DISPLAY FIRST POINT CLASSIFIED                              *00157000
        C LINE   = LINE NUMBER                                                 *00158000
        C LPT    = DISPLAY LAST POINT CLASSIFIED                               *00159000
        C NOCLS  = NUMBER OF CLASSES CLASSIFIED                                *00160000
        C NOCLS5 = NUMBER OF CLASSES IN DISPLAY                                *00161000
        C NOFET5 = NUMBER OF FEATURES USED                                     *00162000
        C NOGRPS = NUMBER OF GROUPS IN DISPLAY                                 *00163000
        C NOMAPS = NUMBER OF MAPS TO BE PRINTED                                *00164000
        C NOFLD  = NUMBER OF TRAING FIELDS                                     *00165000
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          C NOTST  = NUMBER OF TEST FIELDS                                      *00166000
          C OTRKY  = FLAG TO OUTLINE TRAINING FIELDS                            *00167000
          C OTSKY  = FLAG TO OUTLINE TEST FIELDS                                *00168000
          C PCT    = FLAG TO PRINT TEST FIELD PERCENTAGES                       *00169000
          C PINT   = DISPLAY POINT INTERVAL                                     *00170000
          C PISAM  = FIRST SAMPLE FOR PERCENT CALCULATIONS                      *00171000
          C PLSAM  = LAST SAMPLE FOR PERCENT CALCULATIONS                       *00172000
          C PPINT  = POINT INTERVAL FOR PERCENT CALCULATIONS                    *00173000
          C PSINT  = SAMPLE INTERVAL FOR PERCENT CALCULATIONS                   *00174000
          C PTS    = NUMBER OF SAMPLES CLASSIFIED                               *00175000
          C RDCNT  = SAVTAP READ COUNT                                          *00176000
          C RUNNUM = RUN NUMBER TO DEFINE AREA DISPLAYED                        *00177000
          C SAVMAP = FORTRAN UNIT NUMBER FOR SCRATCH DISK                       *00178000
          C SERIAL = SERIAL NUMBER OF FILE TO BE DISPLAYED                      *00179000
          C STATKY = FLAG TO PRINT REDUCED STATISTICS                           *00180000
          C SYMCNT = NUMBER OF SYMBOLS IN ARRAY SYMMTX                          *00181000
          C SYMMTX = SYMBOLES TO BE USED ON MAP                                 *00182000
          C THRES  = THRESHOLD VALUES                                           *00183000
          C THSCNT = NUMBER OF THRESHOLDS INPUT                                 *00184000
          C TRCLS  = FLAG TO PRINT TRAINING CLASS PERFORMANCE                   *00185000
          C TRFLD  = FLAG TO PRINT TRAINING FIELD PERFORMANCE                   *00186000
          C TSCLS  = FLAG TO PRINT TEST CLASS PERFORMANCE                       *00187000
          C TSFLD  = FLAG TO PRINT TEST FIELD PERFORMANCE                       *00188000
          C WRCNT  = SAVTAP WRITE COUNT                                         *00189000
          C***********************************************************************00190000
ISN 0038        REAL*8         DBLANK                                            00191000
ISN 0039        REAL*4         VR(1),CCN(NOCLS)                                  00192000
ISN 0040        INTEGER*2      TRNTAB(NOCLS5,NOFLD)   ,TSTTAB(NOCLS5,NOTST),     00193000
               *               IR(1)                                             00194000
ISN 0041        INTEGER*4      TSTFLD(10,NOTST),TRNFLD(10,NOFLD)                 00195000
ISN 0042        INTEGER*4      NRETRY,WLF,COUNT,ERROR,                           00196000
               *               SAMPLE,BADLIN,POINT,                              00197000
               *               TNSTRT,TNSTOP,TSSTRT,TSSTOP,                      00198000
               *               PTSCNT,SCC,LPTP,QUIT,FMT(7),LINID(2),FI(2)        00199000
ISN 0043        INTEGER*4      PASS                                              00200000
ISN 0044        INTEGER*4      STP                                               00201000
ISN 0045        LOGICAL*4      PCONLY                                            00202000
ISN 0046        LOGICAL*1      LF(1),NUMRAL(10),LBLANK                           00203000
ISN 0047        INTEGER*4      XXCNT,XXSTOP                                      00204000
ISN 0048        REAL*8         BUF(45)                                           00205000
ISN 0049        LOGICAL*1 FRST,SCND,THRD,LAST
ISN 0050        INTEGER*2 IR1(400),IR2(400)
ISN 0051           EQUIVALENCE     (STP,BUF(1))                                      00206000
ISN 0052           EQUIVALENCE     (DWORK1(1),SCC),(FMT(1),LF(1)),(BLANK,LBLANK)     00207000
ISN 0053           DATA            NUMRAL/'0123456789'/,CBLANK/'        '/           00208000
ISN 0054           DATA            FMT/'(TXX,I6,2XXXA8,13(T121,A1))'/,FI/',I6,,6X,'/ 00209000
             C***********************************************************************00210000
             C                                                                      *00211000
             C INITIALIZATION                                                       *00212000
             C                                                                      *00213000
             C***********************************************************************00214000
ISN 0055           CALL TOPPW(4)                                                     00214100
ISN 0056       100 WLF    = 1                                                        00215000
ISN 0057           NRETRY = 2                                                        00216000
ISN 0058           PASS=1                                                            00217000
ISN 0059           IPTP=IPT                                                          00218000
ISN 0060       101 LINCNT=0                                                          00219000
ISN 0061           IF(NOFLD.LE.0)GO TO 103                                           00220000
ISN 0063           DO 102 I=1,NOFLD                                                  00221000
ISN 0064           IF(CRUN.EQ.TRNFLD(1,TRNFLD(10,I)))GO TO 103                       00222000
ISN 0066       102 CONTINUE                                                          00223000
ISN 0067           I=I-1                                                             00224000
ISN 0068       103 TNSTRT=I                                                          00225000
ISN 0069           TNSTOP=I                                                          00226000
ISN 0070           IF(NOTST.LE.0)GO TO 106                                           00227000
ISN 0072           DO 104 I=1,NOTST                                                  00228000
ISN 0073           IF(CRUN.EQ.TSTFLD(1,TSTFLD(10,I)))GO TO 106                       00229000
ISN 0075       104 CONTINUE                                                          00230000
ISN 0076           I=I-1                                                             00231000
ISN 0077       106 TSSTRT=I                                                          00232000
ISN 0078           TSSTOP=I                                                          00233000
ISN 0079           PTSCNT = 0                                                        00234000
ISN 0080           FRST=.FALSE.
ISN 0081           SCND=FRST
ISN 0082           THRD=FRST
ISN 0083           LAST=FRST
ISN 0084           LIN2=1
ISN 0085           LIN3=1
ISN 0086           KCT=0
ISN 0087           XXCNT =0                                                          00235000
ISN 0088           QUIT   = 0                                                        00236000
ISN 0089           FMT(2) = FI(1)                                                    00237000
ISN 0090           NXLIN  = DILIN                                                    00238000
ISN 0091           LPTP   = LPT                                                      00239000
ISN 0092            IF (NPD .GT. III) LPTP = PINT*110+IPTP                            00240000
ISN 0094            IF(LPTP.GT.LPT)LPTP=LPT                                           00241000
ISN 0096            M       = (54-NPD/2)                                              00242000
ISN 0097            IF (M .LT. 2) M = 2                                               00243000
ISN 0099            DO 105 I=3,11,8                                                   00244000
ISN 0100            LF(I)   = NUMRAL(M/10+1)                                          00245000
ISN 0101            LF(I+1)= NUMRAL(M-M/10*10+1)                                      00246000
ISN 0102            M       = (NPD+7)/8                                               00247000
ISN 0103        105 IF (M .GT. 14) M = 14                                             00248000
ISN 0105        110 EADLIN = 0                                                        00249000
              C***********************************************************************00250000
              C                                                                      *00251000
              C READ MAFTAP CLASSIFICATION LINES AND TABULATE RESULTS                 *00252000
              C                                                                      *00253000
              C***********************************************************************00254000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00255000
              C READ CNE RECORD                                             +          00256000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00257000
ISN 0106        120 IF (LIN3.EC.0) GO TO 180
ISN 0108            DO 15 I=1,FTS
ISN 0109            IR1(I)=IR2(I)
ISN 0110         15 IR2(I)=IF(I)
ISN 0111            COUNT   = RDCNT                                                   00261000
ISN 0112            CALL TOPRD(4,COUNT,ERROR,LINID,NRETRY,WLF)                        00262000
ISN 0113            LINCNT = LINCNT+1                                                 00263000
ISN 0114            IF (ERROR-1) 130,1800,121
ISN 0115       1800 LAST=.TRUE.
ISN 0116            GO TC 45
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00265000
              C HANDLE READ ERROR                                           +          00266000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00267000
ISN 0117        121 EADLIN = BADLIN + 1                                               00268000
ISN 0118            I       = (LINCNT-1)*CLINT+CILIN                                  00269000
ISN 0119            WRITF (6,1210) I,ERRCR,CCUNT                                      00270000
ISN 0120       1210 FORMAT (' ****** CLASSIFICATION LINE'I6,' READ FROM MAP TAPE WITH 00271000
                   *ERRCR CODE'I2,' COUNT WAS'I7,'.')                                 00272000
ISN 0121            STOP                                                              00273000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00274000
              C IS THIS LINE REQUESTED                                      +          00275000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00276000
ISN 0122        130 IF (FRST) CC TO 45
ISN 0124            IF (.NCT.SCND) GC TO 5
ISN 0126           FRST=.TRUE.
ISN 0127           GO TC 45
ISN 0128         5 IF (.NCT.THFD) GO TO 10
ISN 0130           SCND=.TRUE.
ISN 0131           CO TC 45
ISN 0132        10 THRD=.TRUE.
ISN 0133        45 LIN2=LIN3
ISN 0134           LIN3=LINID(1)
ISN 0135           IF (LIN3.EG.0) LAST=.TRUE.
ISN 0137           PCCNLY = .TRUE.                                        00279000
ISN 0138           IF (LIN2.GE.NXLIN) PCONLY=.FALSE.
ISN 0140           IF (NXLIN.CT.DLLIN) FCCNLY=.TRUE.                      00281000
ISN 0142           IF(LIN2.GT.DLLIN) PCONLY=.TRUE.
ISN 0144           IF (      FCONLY     .ANC.  CALC .NE. 0) GC TO 120     00283000
ISN 0146           LAG=LIN2-DLINT
ISN 0147           LEAC=LIN2+CLINT
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ 00286000
            C THRESHCLD IF RECUESTED                                      +   00287000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ 00288000
ISN 0148       140 IF (THSCNT .LE. 0)GO TO 150                            00289000
ISN 0150           DO 142 SAMPLE = 1,PTS                                  00290000
ISN 0151           K      = IR(SAMPLE)                                    00291000
ISN 0152           IF (VR(SAMPLE) .LT. (CCN(K)-.5*THRES(2,K)))IR(SAMPLE) = NOCLS5
ISN 0154       142 CONTINUF                                               00293000
ISN 0155       150 CONTINUE
ISN 0156           IF (.NOT.SCND) GO TO 120
ISN 0158           IF (.NOT.FRST) GC TO 75
ISN 0160           IF (LAST) CC TO 75
ISN 0162           IP2=PTS-1
ISN 0163           I=2
ISN 0164        65 CONTINUE
ISN 0165           IF (IR2(I-1).NE.IR2(I+1)) GO TO 40
ISN 0167           IF (IR1(I).NE.IR (I)) GO TO 40
ISN 0169           IF (IR1(I).NE.IR2(I-1)) GO TO 40
ISN 0171           IF (IR2(I).EQ.IR1(I)) GO TO 40
ISN 0173           IF (IR1(I).EC.NOCLS5) GO TC 40
ISN 0175           IR2(I)=IR1(I)
ISN 0176           I=I+1
ISN 0177           KCT=KCT+1
ISN 0178        40 I=I+1
ISN 0179           IF (I.LE.IF2) GO TO 65
ISN 0181        75 CONTINUE
```

```
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00294000
            C UPDATE TFAININC FIELD POINTERS                             +  00295000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00296000
ISN 0182          IF (CALTRN+CTRKY) 153,153,151
ISN 0183      151 K       = TNSTOP + 1                                     00298000
ISN 0184          IF(K .GT. NCFLD ) GO TC 152                              00299000
ISN 0186          IF(TRNFLD(2,TRNFLD(10,K)).GT.LEAD)GO TO 152              00300000
ISN 0188          TNSTCP = K                                               00301000
ISN 0189          GO TO 151                                                00302000
ISN 0190      152 IF(TRNFLD(3,TRNFLD(10,TNSTRT)).GE.LAG)GO TO 153          00303000
ISN 0192          K       = TNSTRT + 1                                     00304000
ISN 0193          IF (K .GT. NCFLD) GO TC 153                              00305000
ISN 0195          TNSTRT = K                                               00306000
ISN 0196          GO TC 152                                                00307000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00308000
            C UPDATE TEST FIELD POINTERS                                 +  00309000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00310000
ISN 0197      153 IF (CALTST+CTSKY) 156,156,154                             00311000
ISN 0198      154 K       = TSSTCP + 1                                     00312000
ISN 0199          IF (K .GT. NOTST) GO TC 155                              00313000
ISN 0201          IF(TSTFLD(2,TSTFLD(10,K)).GT.LEAD)GO TO 155              00314000
ISN 0203          TSSTCP = K                                               00315000
ISN 0204          GO TO 154                                                00316000
ISN 0205      155 IF(TSTFLD(3,TSTFLD(10,TSSTRT)).GE.LAG)GO TO 156          00317000
ISN 0207          K       = TSSTRT + 1                                     00318000
ISN 0208          IF (K .GT. NCTST) GO TO 156                              00319000
ISN 0210          TSSTRT = K                                               00320000
ISN 0211          GO TO 155                                                00321000
ISN 0212      156 IF(PASS.GT.1)GO TO 160                                   00322000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00323000
            C TALLY TFAINING PERFORMANCE                                 +  00324000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00325000
ISN 0214          IF(CALTRN) 158,158,157                                   00326000
ISN 0215      157 CALL PCTTAL(TRNFLD,TPNTAB,TNSTRT,TNSTCP,NOFLD,IR2)
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00328000
            C TALLY TEST PERFORMANCE IF FECUESTED                        +  00329000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00330000
ISN 0216      158 IF (CALTST) 160,160,159                                  00331000
ISN 0217      159 CALL PCTTAL(TSTFLD,TSTTAB,TSSTRT,TSSTCP,NOTST,IR2)
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00333000
            C OUTLINE TRAINING FIELDS                                    +  00334000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++  00335000
```

```
ISN 0218       160 IF (PCONLY) GO TO 170                                           00336000
ISN 0220           CO 50 I=1,PTS
ISN 0221        50 IR1 (I)=IR2(I)
ISN 0222       161  IF (OTRKY) 165,165,162                                         00337000
ISN 0223       162 CALL FLDBOR(TPNFLD,TNSTRT,TNSTOP,IR1 ,1)
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00339000
             C OUTLINE TEST FIELDS                                       +         00340000
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00341000
ISN 0224       165 IF (OTSKY) 170,170,166                                          00342000
ISN 0225       166 CALL FLDBOR(TSTFLD,TSSTRT,TSSTOP,IR1 ,2)
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00344000
             C PRINT MAP                                                 +         00345000
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00346000
ISN 0226       170 IF (NOMAPS) 120,120,171                                         00347000
ISN 0227       171 IF (PCONLY) GO TO 120                                           00348000
ISN 0229           NXLIN  = NXLIN+DLINT                                            00349000
ISN 0230           J      = 1                                                      00350000
ISN 0231           DO 173 I=1,14                                                   00351000
ISN 0232       173 DWORK1(I)=DBLANK                                                00352000
ISN 0233           DO 172 I=IFTP,LPTP,PINT                                         00353000
ISN 0234           LWORK(J) = SYMMTX (IR1 (I))
ISN 0235       172 J        = J+1                                                  00355000
ISN 0236           PTSCNT = PTSCNT+J-1                                             00356000
ISN 0237           WRITE(6,FMT) LIN2,DWORK1
ISN 0238           WRITE (9) LIN2,DWORK1
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00358000
             C BLOCK MAP 3 LINES PER RECORD TO SAVE MAP ON DISK          +         00359000
             C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++         00360000
ISN 0239           IF (.NOT.SAVLIN) GO TO 120                                      00361000
ISN 0241           XXCNT=XXCNT+1                                                   00362000
ISN 0242           ILOC=(XXCNT-1)*15+1                                             00363000
ISN 0243           BUF(ILOC)=LIN2
ISN 0244           DO 591 I=1,14                                                   00365000
ISN 0245     591   BUF(I+ILOC)=DWORK1(I)                                           00366000
ISN 0246           IF(XXCNT.LT.3)GO TO 595                                         00367000
ISN 0248           WRITE(SAVMAP,5910)BUF                                           00368000
ISN 0249     5910  FORMAT(45A8)                                                    00369000
ISN 0250           XXCNT=0                                                         00370000
ISN 0251           BUF(1)=0                                                        00371000
ISN 0252           BUF(16)=0                                                       00372000
ISN 0253           BUF(31)=0                                                       00373000
ISN 0254     595   CONTINUE                                                        00374000
ISN 0255            GO TO 120                                                        00375000
ISN 0256        180 IF(XXCNT.GE.1.AND.SAVLIN)WRITE(SAVMAP,5910)BUF                   00376000
ISN 0258            XXCNT=0                                                          00377000
ISN 0259            IF(NOMAPS.LE.0)GC TO 251                                         00378000
ISN 0261            IF (.NOT. SAVLIN) GO TO 182                                      00379000
ISN 0263        181 WRITE(SAVMAF,1821) STOPCC                                        0038C000
ISN 0264        182 WRITE(6,1820) PTSCNT,KCT
ISN 0265       1820 FORMAT ('0'120X/41X'NUMBER OF POINTS DISPLAYED ARE'I8,T121,1X/I10)
ISN 0266            IF(.NOT.SAVLIN)GO TO 240                                         00383000
ISN 0268            WRITE(SAVMAP,1820)PTSCNT,KCT
ISN 0269            WRITE(SAVMAP,1821)STCPCD                                         00385000
ISN 0270       1821 FORMAT(A4,T121,1X)                                               00386000
ISN 0271            ENCFILE SAVMAP                                                   00387000
ISN 0272            IF (CUIT .NE. 0) GO TO 252                                       00388000
              C***********************************************************************00389000
              C                                                                      *00390000
              C FINISH MAP PRINTING REQUEST                                          *00391000
              C                                                                      *00392000
              C***********************************************************************00393000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00394000
              C READ MAP AND DISPLAY FROM SAVE CISK                         +          00395000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00396000
ISN 0274            NMAPS=NOMAFS-1                                                   00397000
ISN 0275            IF(NMAPS.LE.0)GO TO 240                                          00398000
ISN 0277            DO 239 IK=1,NMAPS                                                00399000
ISN 0278            REWIND SAVMAP                                                    00400000
ISN 0279            IPASS=0                                                          00401000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00402000
              C COPY HEADER INFCRMATION FRCM DISK                           +          00403000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00404000
ISN 0280        210 READ(SAVMAF,2170)DWORK2,WE2                                      00405000
ISN 0281       217C FORMAT(15AE,A1)                                                  00406000
ISN 0282            IF(SCC.EO.STCPCD)GO TO 218                                       00407000
ISN 0284            WRITE(6,217C)DWORK2,WE2                                          00408000
ISN 0285            GO TO 210                                                        00409000
ISN 0286        218 IPASS=IPASS+1                                                    00410000
ISN 0287            IF(IPASS.LT.2)GO TO 210                                          00411000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00412000
              C UNBLCCK AND CISFLAY MAP FRCM DISK                           +          00413000
              C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++          00414000
ISN 0289      219   XXCNT=XXCNT+1                                                    00415000
ISN 0290            IF(XXCNT.EC.1)READ(SAVMAF,5910)BUF                               00416000
ISN 0292          ILCC=(XXCNT-1)*15+1                                                00417000
ISN 0293          LIN2=BUF(ILCC)
ISN 0294          DO 592 I=1,14                                                      00419000
ISN 0295     592  DWORK1(I)=BUF(I+ILOC)                                              00420000
ISN 0296          IF(XXCNT.FC.3)XXCNT=0                                              00421000
ISN 0298          IF(LIN2.EQ.0)GO TO 219
ISN 0300          IF(STP.EQ.STCPCD)GO TO 225                                         00423000
ISN 0302          WRITE(6,FMT)LIN2,DWORK1
ISN 0303          GO TO 219                                                          00425000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00426000
             C COPY TRAILING INFO FROM DISK                                +         00427000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00428000
ISN 0304       225 REAC(SAVMAP,2170,END=239)DWORK2,WE2                               00429000
ISN 0305          IF(SCC.EQ.STCPCD)GO TO 239                                         00430000
ISN 0307          WPITE(6,2170)DWORK2,WE2                                            00431000
ISN 0308          GO TO 225                                                          00432000
ISN 0309       239 CONTINUE                                                          00433000
ISN 0310       240 IF(NCW.EQ.1)GO TO 251                                             00434000
             C*********************************************************************00435000
             C                                                                    *00436000
             C PREPARE TO PRINT SECOND WIDTH OF MAP                               *00437000
             C                                                                    *00438000
             C*********************************************************************00439000
ISN 0312          REWIND SAVMAP                                                      00440000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00441000
             C PRINT HEADER INFCRMATION FROM DISK                          +         00442000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00443000
ISN 0313       241 REAC(SAVMAF,2170)DWORK2,WE2                                       00444000
ISN 0314          IF(SCC.EQ.STCPCD)GO TO 242                                         00445000
ISN 0316          WRITE(6,2170)DWORK2,WE2                                            00446000
ISN 0317          GO TO 241                                                          00447000
ISN 0318       242 PASS=PASS+1                                                       00448000
ISN 0319          ICNT  = WRCNT                                                      00449000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00450000
             C PRINT AND SAVE NEW CCLUMN HEADER                            +         00451000
             C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00452000
ISN 0320          NPD=NPD-111                                                        00453000
ISN 0321          L=NFD                                                              00454000
ISN 0322          IF(L.GT.111)L=111                                                  00455000
ISN 0324          M=(54-L/2)                                                         00456000
ISN 0325          IF(M.LT.2)M=2                                                      00457000
ISN 0327          DO 201 I=3,11,8                                                    00458000
ISN 0328          LF(I)=NUMRAL(M/10+1)                                          00459000
ISN 0329          LF(I+1)=NUMRAL(M-M/10*10+1)                                   00460000
ISN 0330      201 M=(L+7)/8                                                     00461000
ISN 0331          DO 202 I=1,14                                                 00462000
ISN 0332      202 DWORK1(I)=CBLANK                                              00463000
ISN 0333          J = 3                                                         00464000
ISN 0334          IF (DLSAM.CT.999) J = J+1                                     00465000
ISN 0336          IF (DLSAM.GT.9999) J = J+1                                    00466000
ISN 0338          JB=LPTP+PINT                                                  00467000
ISN 0339          JE=LPT                                                        00468000
ISN 0340          IF(NPD.GT.111)JE=PINT*110+JB                                  00469000
ISN 0342          L       = JE-JB+1                                             00470000
ISN 0343          FMT(2)=FI(2)                                                  00471000
ISN 0344          DO 204 I=1,J                                                  00472000
ISN 0345          M       = (JB-1)*CSINT+CISAM                                  00473000
ISN 0346          N      = 10**(J-I)                                            00474000
ISN 0347          NN      = 1C*N                                                00475000
ISN 0348          CO 203 K=1,L                                                  00476000
ISN 0349          LWORK(K) = NUMRAL((MOD(M,NN)/N)+1)                            00477000
ISN 0350      203 M       = M+CSINT                                             00478000
ISN 0351          WRITE(SAVMAP,FMT)DWORK1                                       00479000
ISN 0352      204 WRITE(6,FMT) DWORK1                                           00480000
ISN 0353          WRITE(6,2040)                                                 00481000
ISN 0354     2040 FORMAT ('0'120X)                                              00482000
ISN 0355          WRITE(SAVMAP,2040)                                            00483000
ISN 0356          FMT(2) = FI(1)                                                00484000
ISN 0357          IPTF=LPTP+PINT                                                00485000
ISN 0358      205 WRITE(SAVMAP,2050)STCPCD                                      00486000
ISN 0359     2050 FORMAT(A4)                                                    00487000
ISN 0360          NDW=NDW-1                                                     00488000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00489000
            C BACKSPACE AND GO BACK TO PRINT REMAINING WIDTHS          +        00490000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00491000
ISN 0361          CALL TOPBS(4,LINCNT,ERROR)                                    00492000
ISN 0362          CO TO 101                                                     00493000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00501000
            C ERROR TERMINATICN                                       +        00502000
            C+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++        00503000
ISN 0363      251 IF (CUIT .EC. 0) GO TO 310                                    00504000
ISN 0365      252 CALL TOPFF(4)                                                 00505000
ISN 0366          FILESV = FILESV+1                                             00506000
ISN 0367      255 WRITE(6,2500)                                                 00507000
ISN 0368      2500 FORMAT ('1****** PROCESSOR STEP WAS TERMINATED BY OPERATOR')       00508000
             C RETURN                                                                 00509000
ISN 0369           RETURN1                                                            00510000
ISN 0370       310 RETURN                                                             00511000
ISN 0371           END                                                                00512000
```

Row 1	C	C	C	R	X	C
Row 2	C	R	C	X	C	C
Row 3	C	C	R	C	O	C

Fig. 1

Some classified data points prior to employing the 4NN rule.

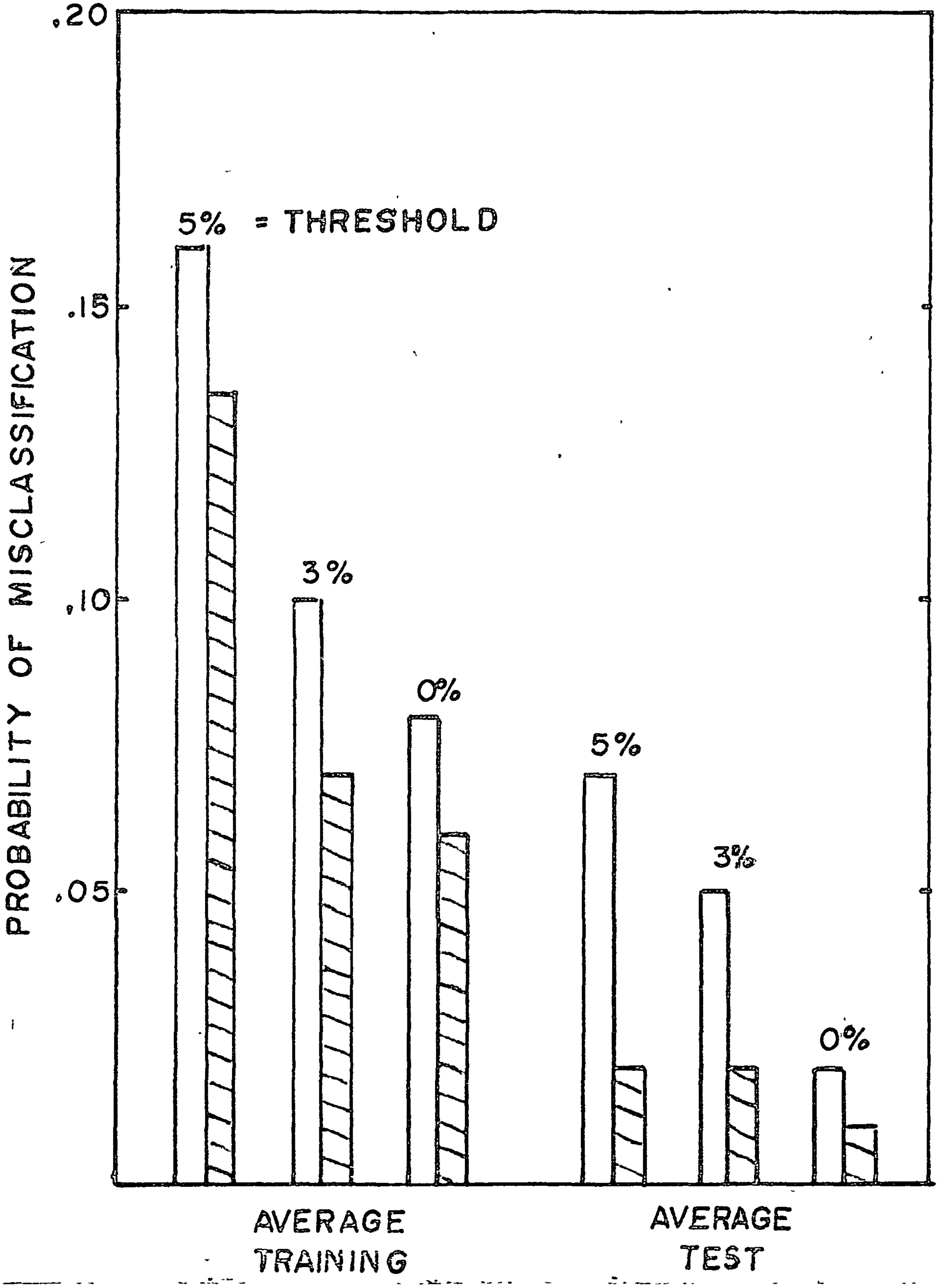

Figure 2

Typical classification results with (shaded areas) and without (unshaded areas) the 4NN algorithm.